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# Rapid Risk Assessment in Industry: Increasing Awareness of Worker Safety in Industrial Activities

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**Abstract:** When training engineers and team leaders, it is crucial to focus on cultivating essential skills for safety at work, required in both theoretical design and practical application. One such crucial skill is the ability to assess professional risks across all engineering domains. To promote sustainable safety awareness in workplaces and to initiate the early education and training of engineering workers through training and testing, we developed a software application and tested it among Romanian workers. This software facilitates the management of the entire risk assessment process, further enhancing the training experience. The presented methodology used for learning, testing, and assessing the skills of engineering workers and for risk assessment, called EL-PRAI (Engineering Learning and Professional Risks Assessment in Industry), was tested on 238 workers (engineers and team leaders) from different engineering fields. The results obtained and the workers' positive feedback support a broader use of the software application for educating engineers and team leaders on workplace safety. If the engineers and team leaders understand the risks at their workplaces well, they will be able to properly train their subordinate workers and order appropriate measures before starting activities.

**Keywords:** safety workplace; risk assessment; educational methodology; software package

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## 1. Introduction

Engineering is a vast and complex field that includes disciplines such as mechanical engineering, electrical engineering, chemical engineering, civil engineering, software engineering, and many others. Therefore, engineering education can be specialized in a particular field or provide a general perspective, covering multiple disciplines. Regardless of the engineering discipline, engineers and team leaders must possess skills to identify dangers and risks while also understanding their impact on people, assets, the environment, and workplace safety in general. In the context of sustainable development, as defined by the World Health Organization, occupational health must be considered and, while understanding the risks to which workers are exposed is crucial, the main focus is always on prevention. A sustainable approach to understanding and preventing risks begins as early as possible with the proper comprehensive education of engineers and team leaders.

The fifth industrial revolution, also known as "Industry 5.0" or the human-centered industrial revolution, aims to create a balance between technology and human needs [1–3]. Going beyond the previous revolutions in concept, which focused on automation and efficiency through technology, this stage focuses on the collaboration between people and advanced technologies, including those based on artificial intelligence, where the human factor remains central. In order for this collaboration between man and technology to work correctly and be efficient, adequate training of the workers is needed. Thus, the workers must understand the working mechanisms of the new technologies and the safe way to collaborate with them, so that, in this interaction, the worker does not have any physical or mental harm, because the psychological impact can sometimes be significant. And in this whole system, engineers and team leaders have an essential role, being, on the one hand, a kind of “mediator”, and on the other hand, they have the essential role of training and teaching workers how to “master” the new equipment as efficiently as possible [1–3].

An introduction to engineering education is defined as a process in which knowledge is created by transforming experiences [4] or as an interdependent self-schooling community entity [5]. It has also been referred to in different ways, such as adventure education, outdoor education, challenge education, and environmental education [6,7]. Experimental education and training were considered part of engineering education from the mid-1950s [8], being extensively analyzed in a complex study published in 1976 [4]. Although training centers apply experimental education methods extensively in their curriculum [5], the published literature regarding teaching occupational safety is extremely scarce [9], with some articles on occupational therapy [10], use of protective equipment in production [11,12], disaster risk reduction and safety in companies [13], or articles referring to developing countries [9,11–15]. Occupational health lecturers often use traditional lecturing to convey information, but while effective for presenting information, lectures have limitations in promoting knowledge-building and teaching practical skills to engineers [9,15,16].

The specific situation encountered in Romania over the past 20 years shows that engineers graduating from technical faculties and entering the industrial design and production sector lack basic knowledge about hazards, risks, and how they can affect workers [17,18]. They are unfamiliar with any techniques for assessing these risks, and when such requirements are imposed on them in the field, they turn to safety and health experts, who themselves, for the most part, are only familiar with a single rigid and inadequate risk assessment methodology recommended by certain authorities (like the Labor Inspectorate) for the activities under analysis [17,18].

Another driving factor of this study is recent legislative changes. In Romania, Government Decision number 259/2022 allows the transition from training and documentation with a ballpen or fountain pen to electronic training and documentation in the field of occupational health and safety.

In the literature, EVASAN has been mentioned as a software developed and applied in Romania; however, the model is specifically designed to be implemented in hospitals and other healthcare institutions [19].

This paper presents a new educational and training methodology for learning, testing, and assessing the skills of engineers and team leaders, as well as risk assessment, named EL-PRAI (Engineering Learning and Professional Risks Assessment in Industry), proven to be very effective in practice. The application that was tested with engineers and team leaders was developed on the basis of the ERAI software V.02.65. The software has been described extensively elsewhere since it was the subject of another article [20] previously published by the authors and attracted interest from numerous companies. However, the business environment has noticed that many engineers and team leaders, both beginners or even those more advanced, enter certain production areas with gaps in health and safety at work. This research aims to address the need for continuous training in this field and to start this training as early as possible in order to create the skills to identify hazards and risks, an essential need in a production environment. As such, a pilot project was carried out in which a number of engineers and team leaders used this application concurrently with on-site visits in production. Subsequently, the knowledge acquired by these engineers and team leaders was evaluated in comparison with another group of engineers and team leaders who did not use this software and methodology. The aim was to verify if the results were favorable in order to expand this learning approach to all the engineers and team leaders from several factories.

The EL-PRAI application offered in this paper is meant to clarify the aspects of applying an experiential learning theory [21] in engineering education, focusing on the issues related to teaching the effective prevention of accidents, a systematic and active approach developed through risk management, a scientific tool used in multiple fields of activity, with an important role in enterprise safety management [22–26].

For the current study, the EL-PRAI methodology was applied in two high-risk industrial fields: metal and automotive industries.

The novelty brought by the EL-PRAI methodology lies in the fact that this methodology innovates learning through the following aspects:

- Implements the learning and training process through practice.
- Develops engineers' abilities to perceive hazards and risks in the concrete reality of work situations, essential for the professional development of engineers—especially critical thinking.
- The software application implements a relatively simple risk assessment method and aims for users to be able to identify the danger and the risk and correctly estimate the severity of any possible injury and the probability of its occurrence, taking into account the effectiveness of the existing measures (which must also be identified) and the possible occurrence of dangerous scenarios and, at the same time, training the users to develop skills in proposing effective and concrete measures in relation to the evaluated risks.
- The learning process is dynamic and interactive and results in the continuous improvement of engineers' skills through immediate feedback provided.
- The software application that implements the methodology is necessary, as it manages the entire learning–testing process for all involved engineers and team leaders, eliminating grading errors and providing immediate results.

In the following, the EL-PRAI methodology and the results obtained following the application of this methodology in high-risk industrial fields, such as the metal and automotive industries, are presented. For an easy understanding of the applied method and to follow a logical sequence, we first present the common methods used in employee training, followed by the specifics of the EL-PRAI method, which is based on experiential learning. Also, in the Methods Section, the approach for training and subsequent knowledge assessment of employees will be explained, along with a description of the parameters used and the software application involved. In the Results and Discussion Section, the outcomes of two groups of employees are presented and analyzed: the first trained using the EL-PRAI method and the second trained without the EL-PRAI software V.01.80.

## 2. Methods

Internationally, there are methodologies and standards aimed at training and testing workers in order to prevent the risks of accidents and occupational diseases, such as the Behavior-Based Safety (BBS) Method, LEAN Safety Training, ISO 45001—Occupational Health and Safety Management. The EL-PRAI methodology, during training, also recommends the use of virtual simulations and augmented reality (AR/VR) for training engineers and leaders in the field of workplace safety. Simulations allow to recreate real working conditions, identify risks, and practice interventions without real exposure to hazards. This stage alternates with training sessions in the field, and in this way, the participants become aware of how dangerous situations can occur in a certain work situation.

EL-PRAI focuses on the formation of a proactive attitude, effective communication, and the identification of possible unsafe attitudes during the performance of certain activities. Practically, it aims to train participants to recognize and eliminate situations and factors that can lead to worker injuries. From this point of view, EL-PRAI is also recommended for the training of equipment and construction designers because dangerous scenarios, not only in execution but also in operation and use, must be identified from the conception and design phase. All this demonstrates the significant contribution that this methodology can bring to the security of activities, especially industrial ones.

Engineers and team leaders will have to understand the activities that will be carried out as a result of their project or those they will coordinate. This means understanding what type of workers will participate, what equipment they will operate, and in what environment they will work, among other factors.

The activities requiring risk assessment must be identified and understood from the beginning. Even in seemingly static situations, such as tank farms or the storage of hazardous substances along with their associated traffic routes, these scenarios are considered part of an activity and must be taken into account.

In this stage, different brainstorming methods can be used by the lecturer, including the Socratic method [27], to identify the activities and dangerous scenarios that may occur in the performance of these activities. Socrates, who was a great philosopher and teacher in ancient Greece, argued that the disciplined practice of questions that involve thinking enables the student to examine ideas logically and determine the validity of those ideas.

The technique of Socratic questioning [27] is an effective and sustainable way to find and explore ideas in depth. This method can be used at all levels of education and training and is obviously a very useful tool for teachers and lecturers. The technique can be used in different stages of a learning internship or a project.

Through this approach, lecturers foster engineers' independent thinking. Deep thinking is present as engineers discuss, debate, evaluate, and analyze ideas through the filter of their own thinking and that of those around them. The lecturer can try to expose contradictions in the thoughts and ideas of the participants in order to then guide them to solid and sustainable conclusions so that everything is analyzed in all the essential details and each participant understands how, in different scenarios and situations, they can achieve the objectives safely, but also how unwanted events can occur in a given situation.

The main questions addressed to the engineers and team leaders within this study are as follows: Q1—What can harm the workers? Q2—How, where, and when can harm to workers occur? Q3—What could be the consequences? Q4—What could go wrong? Q5—What happens if the danger gets out of control? These questions have the role of forming certain skills for searching and recognizing dangers and risks, including those that may appear in certain scenarios that, although they may be predictable, are not easily intuited. Obviously, there can be more questions, and they can be adapted to the concrete situation in the field. For this preliminary study, the questions were developed on the basis of experience in the field of occupational safety and health [20]. Also, the participants must train themselves to identify the potential consequences and how to choose the right prevention and protection measures. Even by simply trying to answer these questions, the participants are compelled to analyze a specific situation, and this can significantly improve their skills.

### *2.1. EL-PRAI Method: Applying Experiential Learning Theory in Engineering Education*

Being a concept that expresses the probability of the occurrence of events with negative connotations and their impact, risk is defined in the specialized literature in various ways [28,29], presenting itself in a diversity of forms, taking into account the objectives of risk assessment [30]. Risks can occur globally, in everyday life, in various forms: natural disasters [31], pandemics, natural hazards, complex emergencies [32], floods [33], or in various fields of activity, such as transportation [34], industry [35], etc.

The EL-PRAI methodology presented in this article helps engineers and team leaders understand how hazards or dangerous phenomena can cause accidents, even catastrophes, how important prevention and control measures are, and above all, how effective they are. For this reason, a detailed presentation of the EL-PRAI methodology is necessary.

Professional risk management in a company starts with diagnosing the safety status at the company level. To establish this diagnosis accurately, various techniques and risk assessment methodologies can be employed. Most of these risk assessment methods begin with hazard identification within the analyzed activities, associated risk identification, severity, and probability estimation, and then, using a risk matrix, the risk level is estimated and assessed.

During this process of estimating risk parameters, engineers and team leaders can observe that determining the maximum foreseeable severity is relatively simple. This determination is based on the potential effects the hazard may have on workers and/or the potential property damage it may cause. However, through this observation, the engineers realize the necessity of understanding the nature of the danger in depth.

On the other hand, engineers can observe that the probability of the risk manifesting and producing those effects is sometimes challenging to establish with satisfactory precision.

As seen in Figure 1, the EL-PRAI methodology presents a series of learning-experimentation stages aimed at acquiring skills. An important contribution to this process is also made by the testing conducted at certain key stages, which ensure both the engineer and the instructor that the acquired skills are adequate both quantitatively and qualitatively. The first step involves engaging the engineers in this process, with the instructor playing a particularly important role in this stage. After involvement, the engineers must understand and become aware of the importance of safety aspects in carrying out activities; thus, the engineer will be able to develop critical thinking skills. This is the first important skill that we aim for the engineer or team leader to acquire. In this stage, the engineers will be able to explain and argue hypotheses of possible risk scenarios, and this stage requires an initial verification of the skill acquired up to this point. The next stage involves the engineers assessing risks and forming the most objective attitude possible towards the analyzed risks. This process requires a high level of involvement from both the engineer and the instructor, who, through the practice-based learning process, stimulate the engineer's creativity and innovative possibilities that should lead to the development of decision-making skills, possibly involving complex decisions. The engineers should be able to propose remedial solutions and control measures for hazards, taking into account other external factors in the analyzed process, such as available resources, and demonstrate the effectiveness of the proposed solutions. In this way, the process of developing the engineer's skills in diagnosing concrete situations in production, even from the design phase, and addressing them from a security perspective can be considered complete.

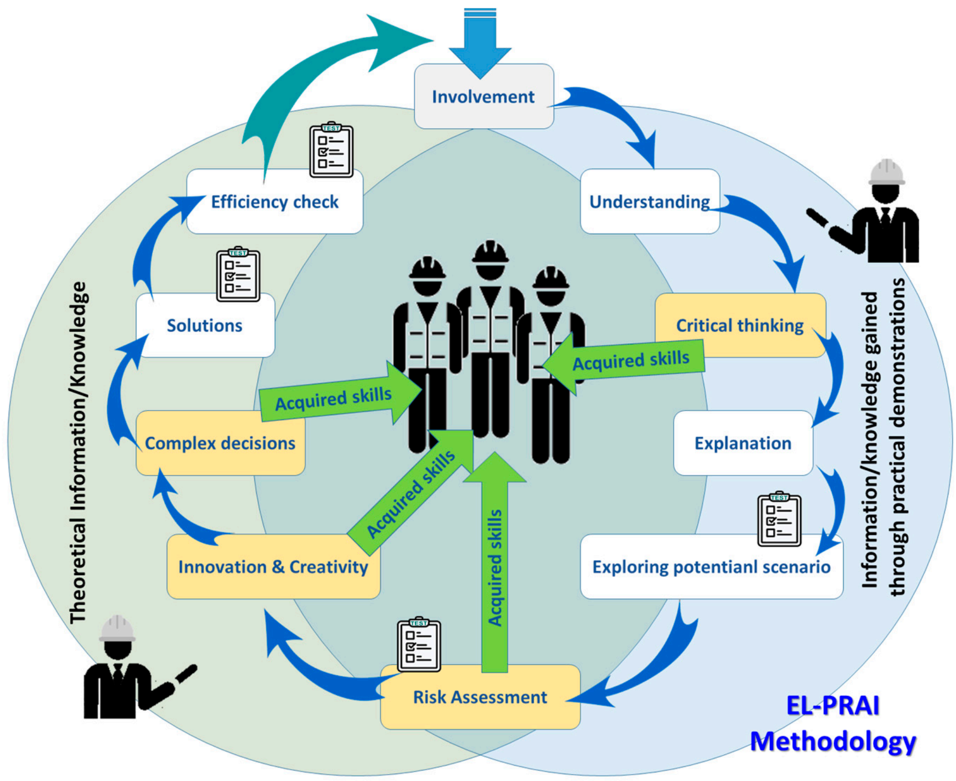



**Figure 1.** Diagram outlining the main stages of learning, experimentation, and acquisition of effective skills in the EL-PRAI methodology.

Detailing some stages, in some technical standards, such as ISO 12100:2010—Safety of machinery—General principles for design—Risk assessment and risk reduction, the probability of injury depends on the frequency and duration of exposure to the hazard, the probability of the occurrence of the dangerous event, i.e., the probability that the hazard will get out of control, as well as the possibility of avoiding the injury. At least the last two aspects depend on the effectiveness of existing prevention and protection measures.

The duration and frequency of exposure to danger generally depend on the workload, but even in this case, we can have some preventive measures to limit exposure to danger or to control it very well.

In the field of professional risk assessment, according to the specialized literature [36–41], various specific software packages have been presented over time. In the scope of this work, we introduce this new methodology for evaluating professional risks in the industry, which we named EL-PRAI.

The EL-PRAI methodology makes a distinction between common industry risks, even those with very high severity, and risks that can lead to catastrophes, such as the explosion of a gas tank.

Additionally, regarding the probability of the identified risk manifesting, EL-PRAI takes into account several essential elements, such as the duration and frequency of exposure to the hazard, the effectiveness of active measures in controlling the danger, or reactive measures that can still prevent harm in case the danger escapes control. It also considers identifying safety deficiencies that can significantly contribute to risk manifestation, potentially nullifying the effect of some effective preventive and protective measures.

Software applications such as EL-PRAI can speed up the process of learning and training through experimentation, diversify it, and build sustainable skills. In current company learning and training stages, engineers and team leaders are typically presented with equipment and technologies, along with their operation and possibly their efficiency in production. In the current study, company internships help engineers and team leaders develop skills in identifying potentially hazardous scenarios where workers could be affected by equipment, products, organizational decisions, locations, etc. By understanding these aspects, engineers and team leaders will be able to create and lead safe projects.

Training and Checking Participants' Knowledge in the Field of Risk Assessment

The methodology presented in this paper has two main objectives: the first is to help engineers and team leaders understand as easily as possible the theoretical and practical aspects related to dangers and risks in any fields related to production activities, and the second is to present a simple but as complete methodology against the dangers and risks that can be encountered in engineering projects in all these fields.

To achieve the first objective, the presented methodology uses a test, verification, and scoring algorithm so that the participants can see and understand their own progress in identifying and evaluating risks, as well as the effectiveness of prevention and protection measures.

For the second objective, to be as complete and applicable as possible, the methodology presented in this article is based on the principles of risk assessment according to ISO 31000:2018 and ISO 12100:2010 technical standards. These standards specify that risk assessment should include three main stages: identification, analysis, and evaluation of risks. Additionally, we studied the list of the most popular risk assessment methodologies applicable in various industrial fields and available in the IEC 31010:2019 standard. By combining all these aspects with real-life situations observed in different industrial domains, the necessity of developing this assessment methodology emerged, aiming to highlight certain aspects less emphasized in other methods, such as the impact that deficiencies in a system, especially if critical, can have on people and material assets.

The software application can be used both to develop workplace safety education and training through training and testing and to facilitate the management of the entire risk assessment process by eliminating calculation errors. A screenshot from this application is presented in Figure 2.

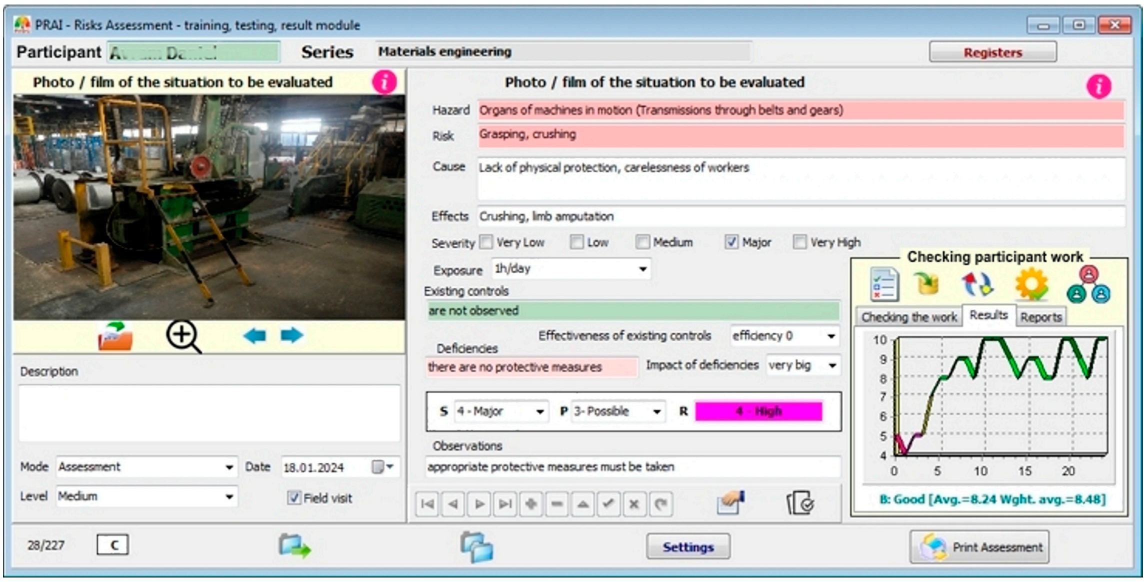



**Figure 2.** Screenshot from EL-PRAI application showing details about the identified risk and its assessment, as well as for evaluating the engineer's performance in understanding this process.

The EL-PRAI software application can contribute to engineering education in several ways by providing tools and resources to facilitate the learning and training process and support the development of the necessary engineering skills. Here are some examples:

1. Simulations and virtual models: Providing simulations and virtual models of engineering concepts and processes, allowing participants to experience and understand the underlying principles without the need for expensive equipment or materials. They can understand the consequences of different risk scenarios in a safe and controlled environment.
2. Virtual labs: Through software applications, participants can conduct experiments and labs in a safe and controlled virtual environment. These virtual labs can provide hands-on learning opportunities and interactions with engineering concepts and theories in a dynamic and engaging way.
3. Design and modeling tools that allow participants to create and analyze risk scenarios from virtual prototypes of their projects. For example, EL-PRAI software can help participants design and visualize the hazards and risks of equipment, installations, or work tasks before their physical implementation.
4. Collaboration platforms: Participants can effectively collaborate on safety and potentially dangerous scenarios that the beneficiaries of their engineering projects will face, even remotely. Collaboration platforms can enable document sharing and joint editing, real-time communication, and managing these project risk scenarios in an integrated and efficient way.
5. Interactive educational resources: Provide access to a variety of interactive educational resources, such as video tutorials, practice exercises, assessment tests, and learning materials tailored to different levels of knowledge and experience.
6. Case studies: The application may include case studies and practical scenarios for risk assessment from different engineering fields, giving participants the opportunity to analyze and make decisions in realistic contexts.
7. Assessment tools: The application can provide tools and templates for risk assessment and management in various situations and areas. Participants can use these tools

to identify and analyze risks associated with their engineering projects and propose appropriate corrective measures.

8. Feedback and continuous improvements: By collecting user data and feedback, the application can be constantly improved to provide a more effective and relevant educational experience. Thus, participants can benefit from better and more adapted risk assessment tools in their future professional practice.
9. Accessibility and flexibility: Access to educational tools and resources anytime, anywhere, for long-life learning.

In the presented risk assessment methodology, certain terms are used with the following meaning:

- Hazard and hazardous phenomenon: Represents any source that can cause harm or material damage. Special attention will be given to hazards that can have a catastrophic impact.
- Maximum foreseeable severity of harm or damage: Considers the maximum foreseeable consequence produced by the source of harm, i.e., the hazard.

It is crucial for engineers and team leaders to recognize that all ergonomic aspects must be considered in risk assessment. This includes factors related to the worker, equipment, tools used, tasks, and work environment. The assessment should cover physical elements like lighting, noise, temperature, humidity, and workspace, as well as psychosocial factors in the work environment. Understanding the importance and relationship between scientific investigations and engineering design in order to solve various problems that may arise daily in the industrial–technological process requires the full involvement of engineers and team leaders through the realization of field-specific innovations [42]. When designing or coordinating a project, engineers and team leaders need to consider all of these aspects. They have a crucial role in determining the risks faced by workers and contribute to the overall evaluation of potential hazards [43].

### 2.2. EL-PRAI Method Parameters

In the EL-PRAI methodology, the severity scale ranges from 1 to 5, considering the chances that harm could occur to a person. However, if the hazard is particularly significant, such as the potential for a large explosion or fire that could cause multiple casualties, an additional value called "Catastrophic" is added and denoted by "C". This will help participants better understand the impact some hazards or dangerous situations can have and how the destructive effects can appear, often in cascade.

Maximum foreseeable severity does not depend on the probability of those consequences occurring but rather on the nature of the hazard and the hazard's potential to produce that maximum harm. For example, in the case of a fall from height, the maximum foreseeable severity is death, the same as in the case of electrocution. In contrast, using a cutter may have a maximum foreseeable consequence of a deep cut or even amputation of a finger, but certainly not death. All these maximum foreseeable consequences have been identified without needing any prior information about their probability of occurrence. However, the probability of these consequences occurring is crucial, which is why it needs to be known as precisely as possible.

To understand the difference between different values of severity level, for instance, between value 5 (Major) and value C (Catastrophic), one must simultaneously take the following into account:

- The nature or potential of the danger that can cause death (e.g., the fall of a worker from a height can cause death—1 death; the collapse of a bridge or a building can cause multiple deaths, while the explosion of a tank or LPG gas installations might affect an entire community);
- The number of people exposed and possibly affected. Depending on the evaluation criteria considered, it can be considered that starting with a number of 2 deaths (from

the same danger/cause and at the same time), we are dealing with a catastrophe, so the severity can be equal to C.

To determine how likely a hazard is to cause harm at the maximum foreseeable severity, more information is needed about both the hazard and the workers who may come into direct or indirect contact with that hazard. This information includes the duration and frequency of exposure to the hazard, i.e., the duration the worker spends in the hazardous area, and thus in a dangerous situation; the effectiveness of active measures that practically control the hazard, including those preventing the occurrence of triggering events that, in the hazardous situation the worker is in, could cause the hazard to get out of control; and the effectiveness of measures reacting to the hazard that has gotten out of control. In addition to this information, another important element in estimating probability is the contribution of existing safety deficiencies to the probability of harm occurrence.

Often, the effects of deficiencies are so significant that they can greatly reduce the effect of active and passive protective measures. Also, deficiencies can favor the occurrence of a hazardous event escaping from control. These aspects, though not exhaustive, should be understood very well by the participants. Then, when planning and carrying out the activities, they will have to identify them and be able to make an assessment of their importance and their influence on workplace safety.

Participants will have to understand the value scales for the parameters that are part of the risk component, how to interpret these value scales, and after gaining experience, even be able to adjust them according to some imposed security criteria. For example, a usual severity scale up to level 5 is presented in Table 1, but a level has been added to the usual scale for the risks with catastrophic effects.

**Table 1.** The severity level(s) based on the maximum foreseeable consequences.

| No. | Severity Level | Observations |
|---|---|---|
| 1 | Minor | Minor injuries, do not require medical care |
| 2 | Slight | The injury is minor and only requires simple first aid |
| 3 | Moderate | The injury is more serious and requires more extensive medical assistance. The worker may be temporarily unable to work and may need limited medical leave |
| 4 | Serious | The injury is severe, possibly involving limb amputation, requiring specialized medical assistance and prolonged treatment. The worker may be absent from work for a significant period |
| 5 | Major | The injury is extremely severe or death |
| C | Catastrophic | The number of fatalities is high. Possible casualties also among the civilian population around the facility |

Table 1 highlights that for hazards with catastrophic impact, meaning a high number of fatalities; the severity level is denoted by "C", and in the calculation formula, C = 10. The duration and frequency of worker exposure to the hazard are crucial factors to consider and are directly proportional to the probability that an exposed worker may be injured.

During the activities, engineers and team leaders will have to identify which prevention and protection measures are already implemented, how and when they act, and what their effectiveness is.

Additionally, the engineers and team leaders will have to observe and identify if there are any deficiencies that may contribute to losing control over the hazard and select the corresponding value from a list like the one presented in Table 2.

When significant deficiencies are identified, according to the values in Table 2, and the hazard can have a catastrophic impact, immediate measures will be taken to stop the activity and remedy the identified deficiencies. The probability (P) of an accident can be estimated. Given that the probability is usually a function of three parameters: the duration and frequency of exposure to the hazard, the effectiveness of existing controls, and the influence of existing deficiencies on safety, according to Equation (1):

$$P = f\,(E, C, D), \tag{1}$$

In this method, the calculation formula for Probability P is presented in Equation (2):

$$P = E + C + D, \tag{2}$$

where P—probability, E—duration and frequency of exposure to the hazard, C—effectiveness of existing controls, and D—influence of deficiencies/weaknesses.

**Table 2.** Deficiencies.

| Values | Descriptions |
|---|---|
| 0 | no deficiencies observed |
| 3 | the observed deficiencies are significant |
| 9 | the observed deficiencies are major |

Equation (2) can undergo changes, allowing participants to assign weight values of 2 or 3 to certain factors to amplify their influence on the likelihood of undesirable outcomes. This enables participants to directly and promptly observe the impact of specific factors on plausibility and safety. For instance, if a worker is situated in an area with significant electromagnetic fields, prolonged exposure increases health risks. Consequently, participants may assign a weight value of 2 or 3 to exposure, promptly recognizing the increased risk to the worker.

Similarly, when a welder is assembling various metal profiles, the participant will be able to observe and evaluate the effectiveness of the welder's personal protective equipment (from this point forward referred to as PPE). In such cases, participants can assign a weight value of 2 or 3 to the estimated efficacy of the control measures, understanding the inverse relationship between control effectiveness and injury probability. As control effectiveness increases, the probability of injury decreases.

After applying Equation (2), the participants will use a risk matrix to identify the level of risk and evaluate it.

In the software application, once the estimated values for severity (S) and probability (P) have been obtained, the corresponding risk level value will be automatically determined from the risk matrix. The risk assessment, meaning the categorization of risk into acceptable or unacceptable categories, will be conducted according to the safety criteria established prior to the evaluation.

In the EL-PRAI application, participants will be graded according to how they identified the dangers and risks, how they determined the possible causes that can lead to the loss of control over the danger, as well as how they identified the possible effects. Depending on these data, the appropriate parameters for severity (S) and probability (P) will be estimated. Moreover, the participants are encouraged to propose appropriate prevention and protection measures.

## 3. Results and Discussion

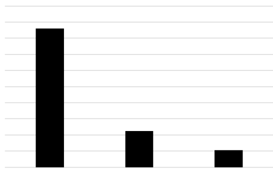
### *3.1. Applying the EL-PRAI Method*

The EL-PRAI methodology was tested on 238 participants in different engineering specialties over a 3-year period. The goal pursued was that, regardless of the engineering field, engineers and team leaders would gain the ability to apply principles of hazard and risk identification. Among the main activities in which the participants were involved and asked to evaluate the risks were those in the field of processing metal objects (construction of bulky and heavy metal structures) and in the automotive field (especially those that require handling masses to and from conveyor belts.

Depending on the results obtained by the participants, both in the risk assessment and in the effectiveness of the proposed measures, the EL-PRAI application gives a score to each participant so that their performance is evaluated, as shown in Table 3. Together with the instructor, the participants identify possible weak points, omissions, or other errors of appreciation in their evaluation, as well as whether the proposed measures were appropriate or not. Thus, the engineers and team leaders continuously improve their performance.

**Table 3.** Number of participants who planned and supervised a series of activities and the results obtained in EL-PRAI.

| | **Theory** | **Field Visits** | **Results Obtained in EL-PRAI *** | | | | |
|---|---|---|---|---|---|---|---|
| | | | **A** | **B** | **C** | **D** | **F** |
| The number of participants | 238 | 182 | 172 | 45 | 21 | 0 | 0 |



* A: Excellent, B: Good, C: Satisfactory, D: Unsatisfactory, F: Failure.

Table 3 shows the number of participants who actually planned and supervised a series of activities. It is noteworthy that all 172 participants who achieved the maximum score were part of the group of 182 participants who attended field visits. This simple observation highlights the importance of on-site practice.

The participants were questioned on how they perceived the ease of learning and applying the EL-PRAI method.

As can be seen from the participants' answers, which are structured in Table 4, the EL-PRAI method is easy to learn and apply for engineers and team leaders, but above all, they answer that this method helps them a lot in understanding the real situation that must be analyzed and evaluated.

**Table 4.** Participant feedback categorized by age and gender.

| | | **Age** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 24–30 | | 31–40 | | 41–48 | | |
| | | **Gender** | | | | | | |
| | | **M** | **F** | **M** | **F** | **M** | **F** | |
| Rate EL-PRAI method's | Performance | 104 | 49 | 44 | 16 | 21 | 4 | TOTAL |
| Ease of learning | Excellent | 97 | 46 | 44 | 14 | 21 | 1 | 223 |
| | Good | 7 | 1 | 0 | 2 | 0 | 3 | 13 |
| | Satisfactory | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| | Week | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ease of practical application of the method | Excellent | 101 | 49 | 44 | 15 | 21 | 2 | 232 |
| | Good | 3 | 0 | 0 | 1 | 0 | 2 | 6 |
| | Satisfactory | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Week | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Impact on understanding, analyzing and evaluating a real situation | Excellent | 101 | 49 | 44 | 14 | 21 | 4 | 233 |
| | Good | 3 | 0 | 0 | 2 | 0 | 0 | 5 |
| | Satisfactory | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Week | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

The verification of the effectiveness of the EL-PRAI method was also carried out by comparing the results obtained by another group of 120 participants who, starting from their already acquired knowledge, were put in front of the same real situations as the initial target group, and the results they obtained were tested.

The results obtained by the two groups of participants are presented in Table 5.

**Table 5.** Results obtained by the two groups of participants.

| | Total Participants | Results Obtained in EL-PRAI [1] | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | F |
| Participants who were trained with the EL-PRAI method | 238 | 172 | 45 | 21 | 0 | 0 |
| Participants who were not trained with the EL-PRAI method | 120 | 19 | 25 | 59 | 12 | 5 |

[1] A: Excellent, B: Good, C: Satisfactory, D: Unsatisfactory, F: Failure.

Participants' results are graphically represented in Figure 3 to highlight and visually depict the significant difference between the two groups of participants in terms of their good recognition and understanding of a field reality.

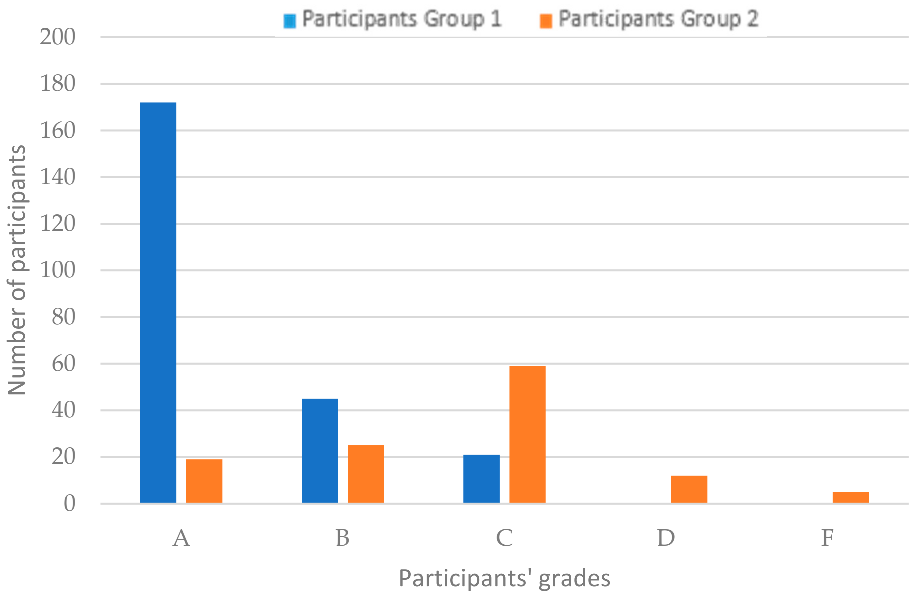



**Figure 3.** Results obtained by the 2 groups of participants, where Participants Group 1—Participants who were trained with the EL-PRAI method; Participants Group 2—Participants who were not trained with the EL-PRAI method: A: Excellent, B: Good, C: Satisfactory, D: Unsatisfactory, F: Failure.

The instructors have the ability to set personalized grading criteria for their course and determine how much these criteria will contribute to the calculation of the participants' final grades. The technology can enhance participant assessment by identifying strengths and weaknesses in their acquired knowledge and skills, guiding them toward the type of information they should focus on and the specific practices they should emphasize for more efficient progress. Additionally, technology provides immediate feedback to participants. From this graph, it is easy to see that the participants who were trained and effectively applied the proposed EL-PRAI method had much better results in the analysis and evaluation of real situations (obtaining grades from A to C); situations that they will obviously face in future activities. The grades of participants who were not trained with the EL-PRAI method are more scattered, with some of them even achieving low results like D or F. The results obtained by the two groups of participants prove that the EL-PRAI methodology, through the learning approach itself, guides them step by step to deeply understand a real situation that they would otherwise unconsciously ignore, developing their abilities for intuitive understanding and quick perception of the actual situation beyond what is usually evident. In other words, it enhances their ability to perceive concrete details that others overlook, despite looking at them every day.

### *3.2. Steps in Applying the EL-PRAI Method*

The steps to be followed in such identification, estimation, evaluation, and control solutions are presented in the block diagram shown in Figure 4.

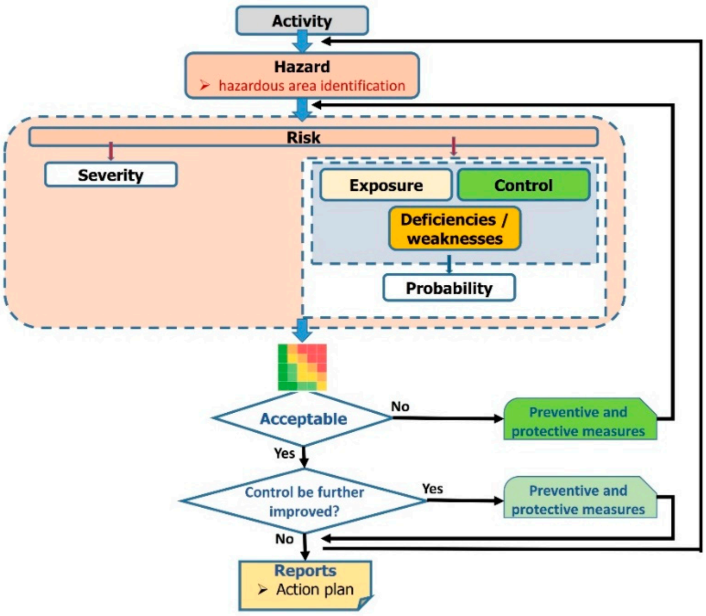



**Figure 4.** Block diagram representing the main steps in applying the EL-PRAI method.

Knowing the activity and observing the workers, the equipment they work with, and the working environment, the evaluation team will identify hazards: "Q1—What can harm the workers?"

After identifying the hazards, the team will identify the risks that each hazard can generate (there may be multiple risks generated by the same hazard). Then, the evaluation team will identify possible hazardous situations in which workers may find themselves: "Q2—How, where, and when can harm to workers occur?" And in response to the question "Q3—What could be the consequences?" the team will be able to answer by understanding the nature of the hazard well. Based on the answers to these questions, for each identified risk, the maximum foreseeable consequence is established, which is determined by the nature of the hazard generating that particular risk.

Establishing the maximum foreseeable consequence helps immediately estimate severity on the corresponding scale, presented in Table 1.

When establishing the maximum foreseeable consequences, existing preventive and protective measures will not be taken into account since, for various reasons, these measures may not fulfill their protective function, and thus, harm can occur at the maximum foreseeable consequence. Usually, these preventive measures aim to reduce the probability of harm by keeping the hazard under control, but if the hazard escapes control, we must consider the maximum foreseeable consequence, meaning we go for the worst-case scenario. After estimating the maximum foreseeable severity of the harm, the evaluation team will identify preventive and protective measures for each identified risk and then assess the effectiveness of these measures in controlling the respective risk.

The question "Q4—What could go wrong?" leads to identifying possible scenarios in which various triggering events can occur and can lead to the hazard escaping control.

It will be analyzed whether existing preventive measures cover these scenarios and also if any deficiencies or vulnerabilities can facilitate triggering events to appear. The degree of influence of these deficiencies upon the hazard will be estimated according to Table 2. Once these elements are identified, Equation (2) is applied, and the occurrence probability is estimated.

Knowing the severity and probability elements, the risk matrix estimates the risk level. The risk is assessed according to preestablished safety criteria. The results can be obtained automatically using software applications, as seen in Figure 5.

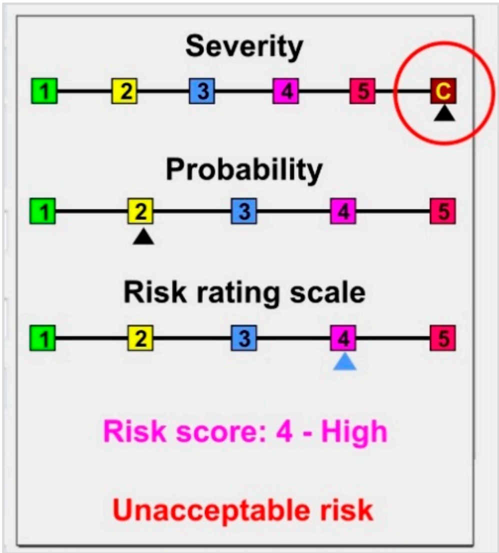



**Figure 5.** Detailed screenshot showing the estimation of S (severity) and P (probability) risk parameters and the risk assessment. 1-5 level of severity, probability and risk rating: 1—negligible, 2—low, 3—moderate/medium, 4—high, 5—very high, C—catastrophic level of risk severity.

Based on the results of the risk assessment, a decision is made regarding the implementation of preventive and protective measures. The effectiveness of reactive protection is analyzed while answering "Q5—What happens if the danger gets out of control?"

It is possible to have some deficiencies in the system. These deficiencies need to be identified, as they have a significant contribution to the probability of the hazard escaping control. Deficiencies should not be confused with triggering events. The difference is that deficiencies exist and can be identified during the risk assessment, whereas triggering events, although identified in risk scenarios, are not always present and do not manifest at the time of assessment. Table 6 shows the impact that these deficiencies can have in situations involving hazards with catastrophic impact as well as medium impact.

From Table 6, it can be observed that deficiencies can significantly contribute to the occurrence of an accident event. Moreover, deficiencies can affect workplace safety even when periodic controls are made. The effect that deficiencies have on the risk level for a hazard with catastrophic impact and for a hazard with moderate impact is presented in Figure 6.

In most cases, the level of risk (R) is particularly high when the severity level (S) is also very high. It should not be overlooked that deficiencies (D) are also present in these situations. It is evident that some hazards can lead to severe, even catastrophic injuries, and as such, some preventive and protective measures may already have been implemented. Deficiencies can arise from various shortcomings and escalating factors that are often overlooked or underestimated despite the preventive measures in place. In other words, often, these existing deficiencies negate the effects of preventive and protective measures. The level of deficiencies shows that instead of being addressed, they either go unnoticed or are ignored, potentially leading to catastrophic accidents.

**Table 6.** The effect of deficiencies in the case of a situation with catastrophic impact and in the case of situations with moderate impact, taking into account the efficiency of existing controls.

| Severity (S) | | E | C | D | P | R |
|---|---|---|---|---|---|---|
| Severity Catastrophic C = 10 | C | 3 | 1 | 0 | 2 | 20 |
| | C | 3 | 1 | 3 | 3 | 30 |
| | C | 3 | 1 | 9 | 5 | 50 |
| | C | 3 | 4 | 0 | 3 | 30 |
| | C | 3 | 4 | 3 | 4 | 40 |
| | C | 3 | 4 | 9 | 5 | 50 |
| | C | 3 | 2 | 0 | 2 | 20 |
| | C | 3 | 2 | 3 | 3 | 30 |
| | C | 3 | 2 | 9 | 5 | 50 |
| Severity Medium | 3 | 3 | 1 | 0 | 2 | 6 |
| | 3 | 3 | 1 | 3 | 3 | 9 |
| | 3 | 3 | 1 | 9 | 5 | 15 |
| | 3 | 3 | 4 | 0 | 3 | 9 |
| | 3 | 3 | 4 | 3 | 4 | 12 |
| | 3 | 3 | 4 | 9 | 5 | 15 |
| | 3 | 3 | 2 | 0 | 2 | 6 |
| | 3 | 3 | 2 | 3 | 3 | 9 |
| | 3 | 3 | 2 | 9 | 5 | 15 |

where E—duration and frequency of exposure to the hazard, C—effectiveness of existing controls, D—the influence of deficiencies/weaknesses, P—probability, R—risk level.

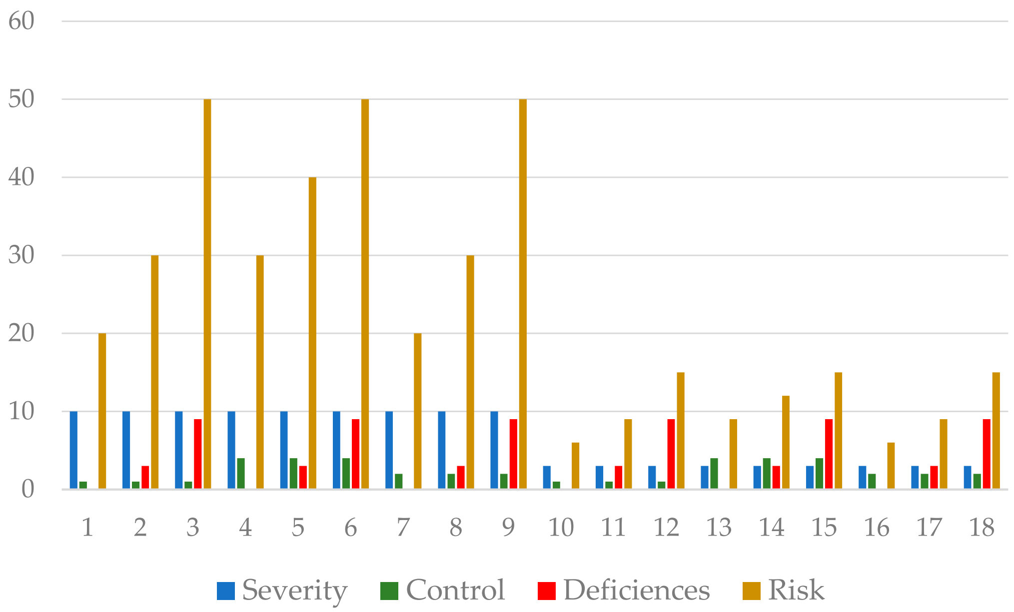



**Figure 6.** The effect that deficiencies have on the risk level for a hazard with catastrophic impact (1–9) and for a hazard with moderate impact (10–18).

Using EL-PRAI software, participants can experimentally learn about the behavior of risks in different situations, including the human factor that must intervene, according to the procedures. Participants can also perform simulations of dangerous situations and can understand the efficiency of controls in dangerous situations. Some results obtained by the participants in specific scenarios are shown in Figure 7.

The five-level scoring system, presented in Figure 7, takes into account the evaluation criteria we have in mind when testing the participants, such as the assessment of the quality of a respondent's answer, as well as the degree of difficulty of the problem/situation to be analyzed. In this sense, each analyzed situation has a weight, which represents the degree of difficulty given by the commission that tests, and a scoring grid in which the commission chooses the ranges of points that fall into the 5 levels.

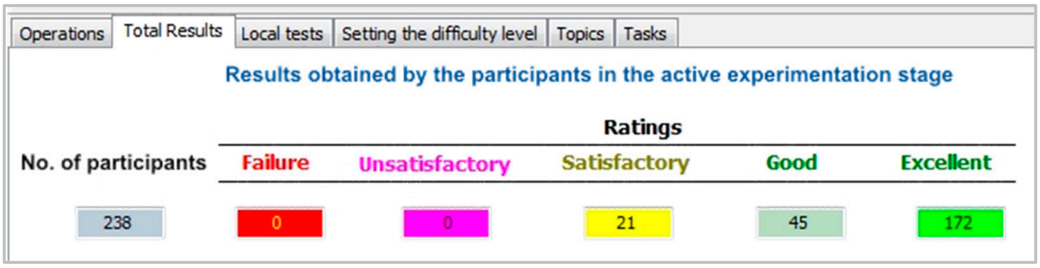



**Figure 7.** The results obtained by participants in the active stage of experimentation.

In practice, many responsible for safety at work, in the beginning, tend to insist too much on details that are obviously (for someone with experience) insignificant, and when they arrive, after much time and effort, at this conclusion, they are often disappointed by the fact that expectations were not confirmed. The instructor can guide participants towards an objective approach, which eliminates any conscious or less conscious limitation in thinking. For example, in situations where hazards with high, catastrophic risks are identified, the participants must identify and pay special attention to active risk prevention measures. This means that hazards must be kept under effective control.

The evaluation team, consisting of engineers and team leaders, must critically analyze how the hazard can be efficiently kept under control while also assessing any triggering events in different risk scenarios.

In order to avoid subjective decisions, even in the estimation of the risk level, multiple criteria are used, which include identifying the risk assessment criteria relevant to the company (e.g., impact on safety, frequency of occurrence, costs) and the weighting of criteria and risks regarding their importance, including according to the goals established in the company's policy and taking the decision to implement the measures based on the prioritization of the risk levels thus established [44,45].

At the same time, the effectiveness of reactive protection measures will be analyzed. The next question to be answered is "Q5—What happens if the danger gets out of control?" These measures aim to prevent injuries, protect against material damage, minimize impacts, and facilitate recovery by restoring the system to a safe condition. Additionally, they help identify deficiencies in equipment, operational procedures, work environment, and hazard location, allowing necessary improvements to be made.

For a more complete and accurate picture of the results obtained during the stage of identifying and evaluating risks, it is necessary to correlate several factors, like understanding the dangers and how they act; understanding the maximum foreseeable impact that the dangers can have; and perhaps the most difficult aspect, estimating the probability to actually produce unwanted effects. Of course, in any estimation process, there is a certain degree of subjectivity, but as experience increases, engineers and team leaders learn to control subjectivity, gather technical arguments, and document their opinions.

The EL-PRAI methodology, after its application, proved its validity in practice, since the results obtained by the subjects tested and trained with this method were significantly better than the subjects not trained with this method. Also, the subjects trained with this methodology were from different fields of activity, with very different dangers and risks, both in terms of the severity of the consequences and the probability of occurrence, and the results obtained by them were very good, as predicted. The theoretical part of the methodology was fully confirmed in practice in most aspects that involve knowledge, awareness, and attitude of the tested subjects towards the more or less dangerous situations that they and the workers in the company face. Although from certain statistical points of view it can be considered that the number of subjects involved is relatively small, by the degree of generalization from the use of the method in industrial fields, we can conclude that the limits of this methodology are very few, and the possible limitations cannot be linked to the number of subjects involved; a number that was found to be relevant and sufficient. External validity might be harder to estimate, since different fields of industry, different work environments, or even workers from different countries may respond differently in certain situations [46].

## 4. Conclusions

Given the emerging technologies in all fields of industry, along with recent Romanian legislative changes in risk assessments and workplace safety enhancement, the need to train engineers and team leaders using new software and methodologies has arisen.

This paper introduces a new methodology for risk assessment, named EL-PRAI, specifically adapted for the learning and training, understanding, and practical experimentation needs of engineers and team leaders. Thus, it incorporates a professional risk assessment approach tailored to engineering fields, highlighting situations where the effects of risk manifestation range from minor to major or even catastrophic.

Two significant contributions can be mentioned in order to facilitate a more precise diagnosis of situations in various factories and industrial plants. Firstly, we emphasized a dual value for risks with maximum foreseeable severity as catastrophic, and secondly, we highlighted with an exponential value the impact that identified deficiencies can have on workplace safety. Practicing with EL-PRAI promotes long-term improvement of the learning process and educational infrastructure across multiple disciplines and levels. It also provides a comprehensive, practical understanding of potential workplace hazards, equipping engineers and team leaders with the skills needed to address significant challenges they can meet in the industrial environments in which they operate.

Testing the EL-PRAI methodology on 238 participants from engineering fields involving high risks, such as the metal processing industry and automotive industry, showed that the majority of engineers and team leaders trained with EL-PRAI were able to identify hazardous situations in specific workplaces. The results obtained (excellent—172 participants, good—45 participants, satisfactory—21 participants, unsatisfactory—0 participants, failure—0 participants) support a broader use of this software application for educating and training engineers and team leaders on workplace safety.

Nevertheless, the methodology presented can be further refined to enhance diagnostic accuracy, a direction that will be explored in our future research.

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**Institutional Review Board Statement:** All the authors assert that all methods contributing to this work comply with the ethical standards of the national and institutional committees on human rights, with the regulations and rights of the workers, and with the Helsinki Declaration of 1975, as revised in 2008. Registration number of the ethical declaration is AEX1370 from 31 March 2021.

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